DEVELOPMENT OF A DETECTION AND EARLY WARNING SYSTEM FOR MALARIA RISK IN THE AMAZON

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THE PERUVIAN AMAZON

- Over 90% of malaria in the Western Hemisphere is located in the Amazon

- In Peru, 75% of malaria cases occur in the Department of Loreto, in the Northern Amazonian Region, and most cases (80%) are concentrated in just 10 of the department's 51 districts.

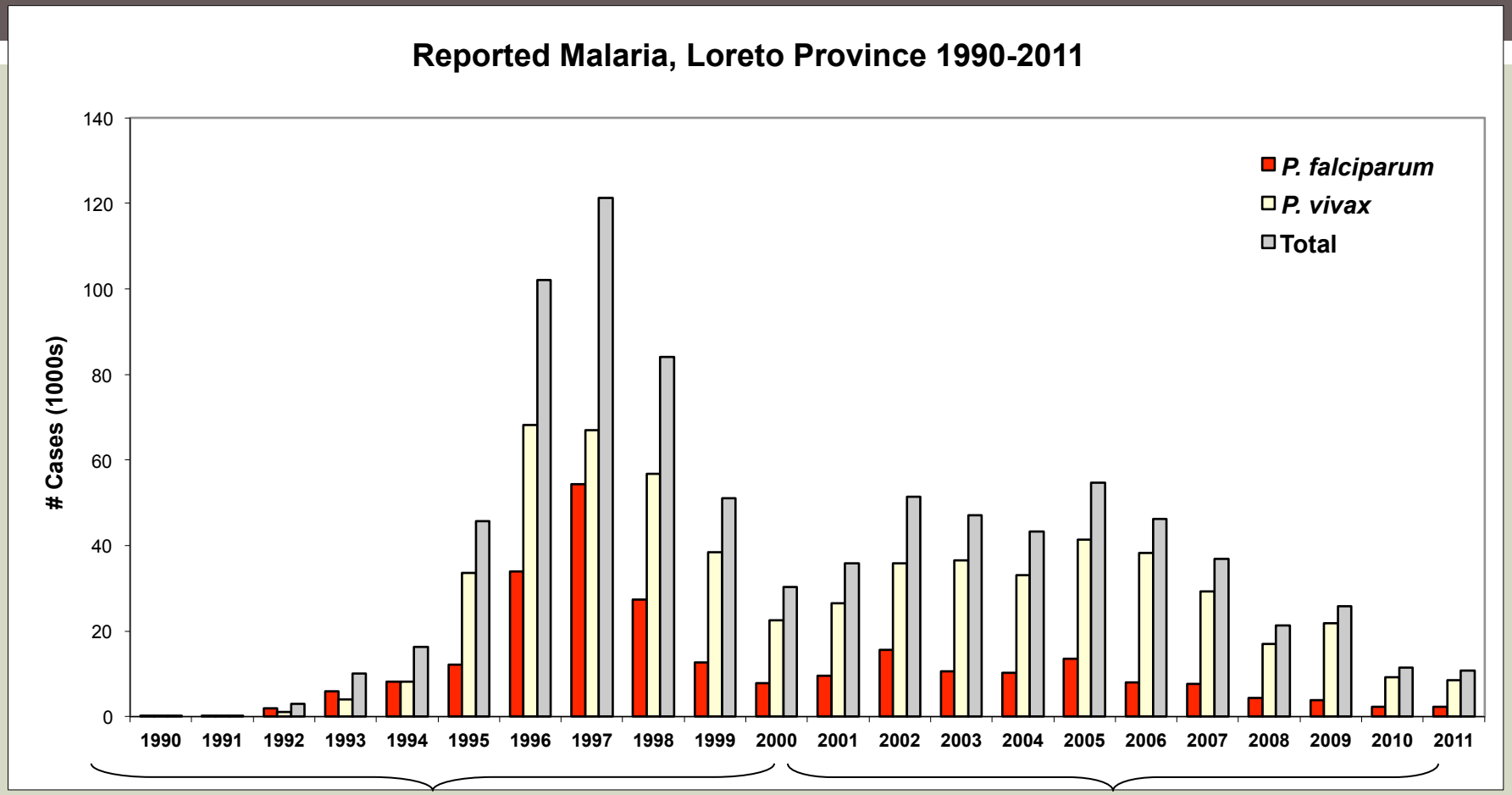
- Key factors related to continued malaria endemicity:
  - expansion of vector habitats from land use change (deforestation for logging and road development)
  - social and ecological processes that increase human exposure *Anopheles darlingi*

AIMS

Feasibility Study: develop a spatially explicit model of malaria transmission risk on the basis of predicted *Anopheles* density and mapped human settlement and activity patterns

End application: operational risk monitoring system to inform decisions on resource distribution and vector management by our collaborators (PRISMA, State Health Ministry, US NMRCD)

MALARIA IN PERU



Highest Deforestation Rate in Peru

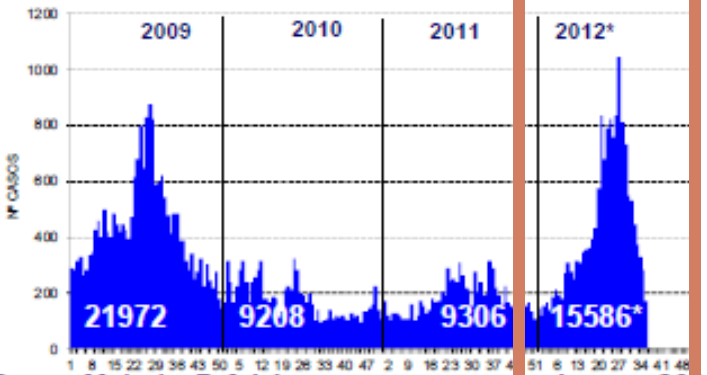
Iquitos-Nauta Road Paving &
Fujimori logging concessions

Roll Back Malaria
& Amazon Malaria Initiative

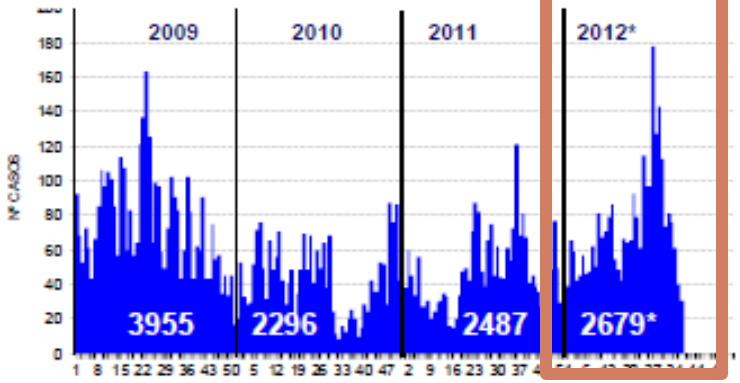
2nd highest increase in malaria cases among Amazon-Basin countries

MALARIA ON THE AMAZON FRONTIER

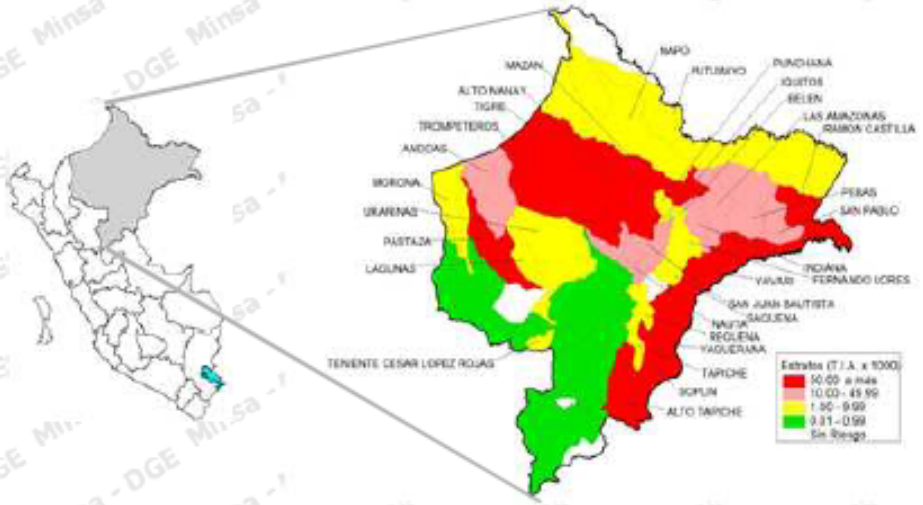
Casos Malaria *P. vívax* por semana. Loreto 2009-2012



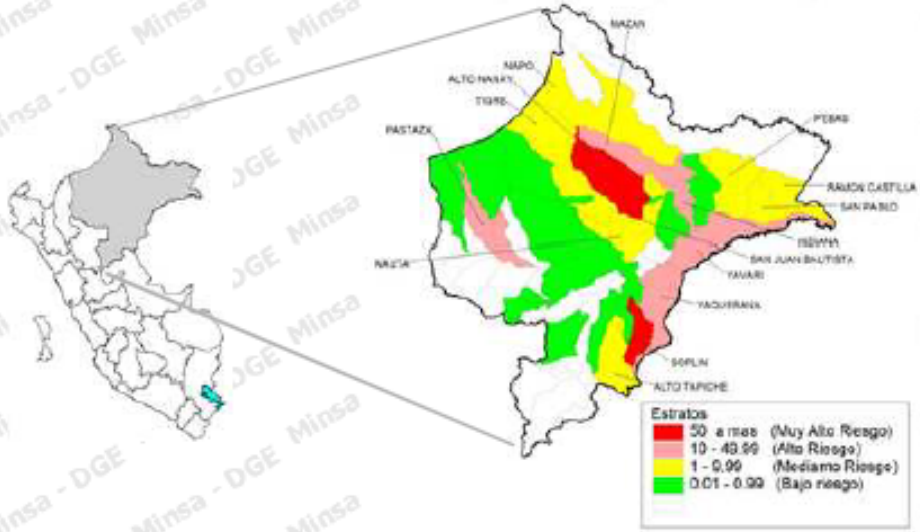
Casos Malaria *P. falciparum* por semana. Loreto 2009-2012



Mapa de malaria por *P. vívax a la SE 36 - 2012*



Mapa de malaria por *P. falciparum a la SE 36 - 2012*

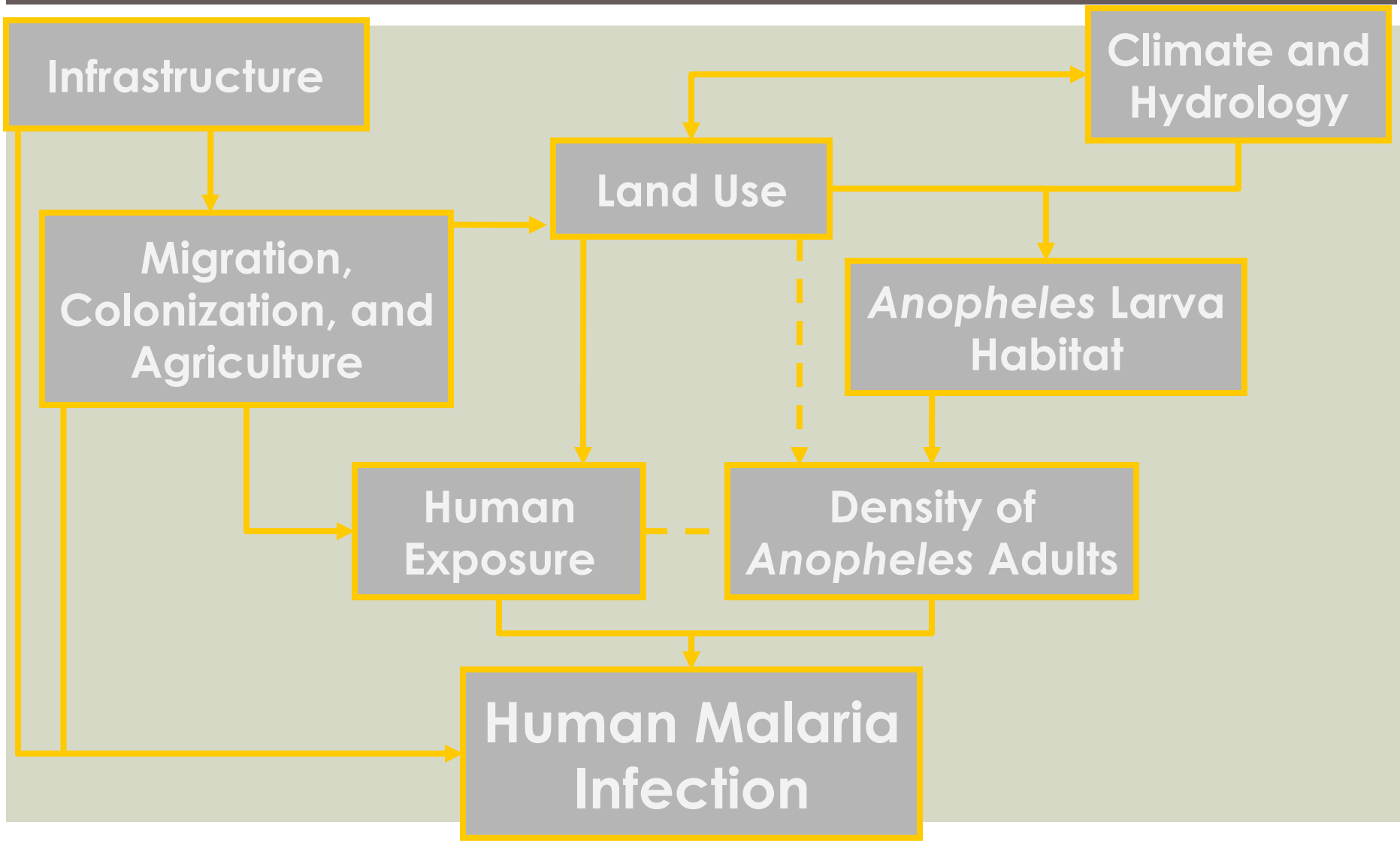


Casos de malaria por especies en Departamento de Loreto, comparado los años 2007 – 2011

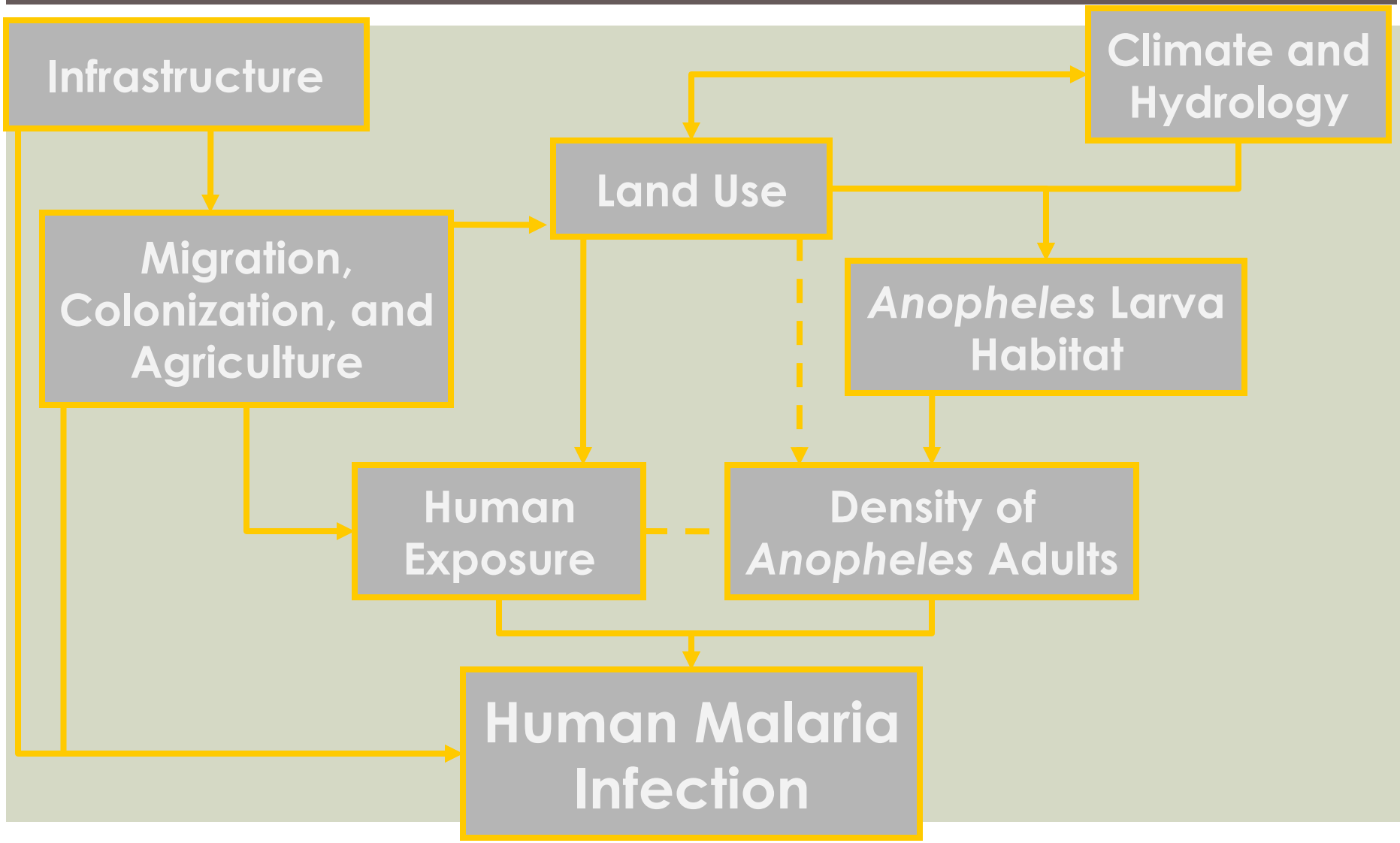
Tipo Dx	2,007	2,008	2,009	2,010	2,011
P. Vivax	29399	20565	21972	9208	9306
P. Falciparum	7609	4489	3878	2238	2473
M. Mixta	144	109	77	58	14
Notificados	37,152	25,163	25,927	11,504	11,793
Defunciones	2	1	2	0	0

FUENTE : RENACE – DGE – MINSA
(*) Hasta la SE 36. 2012

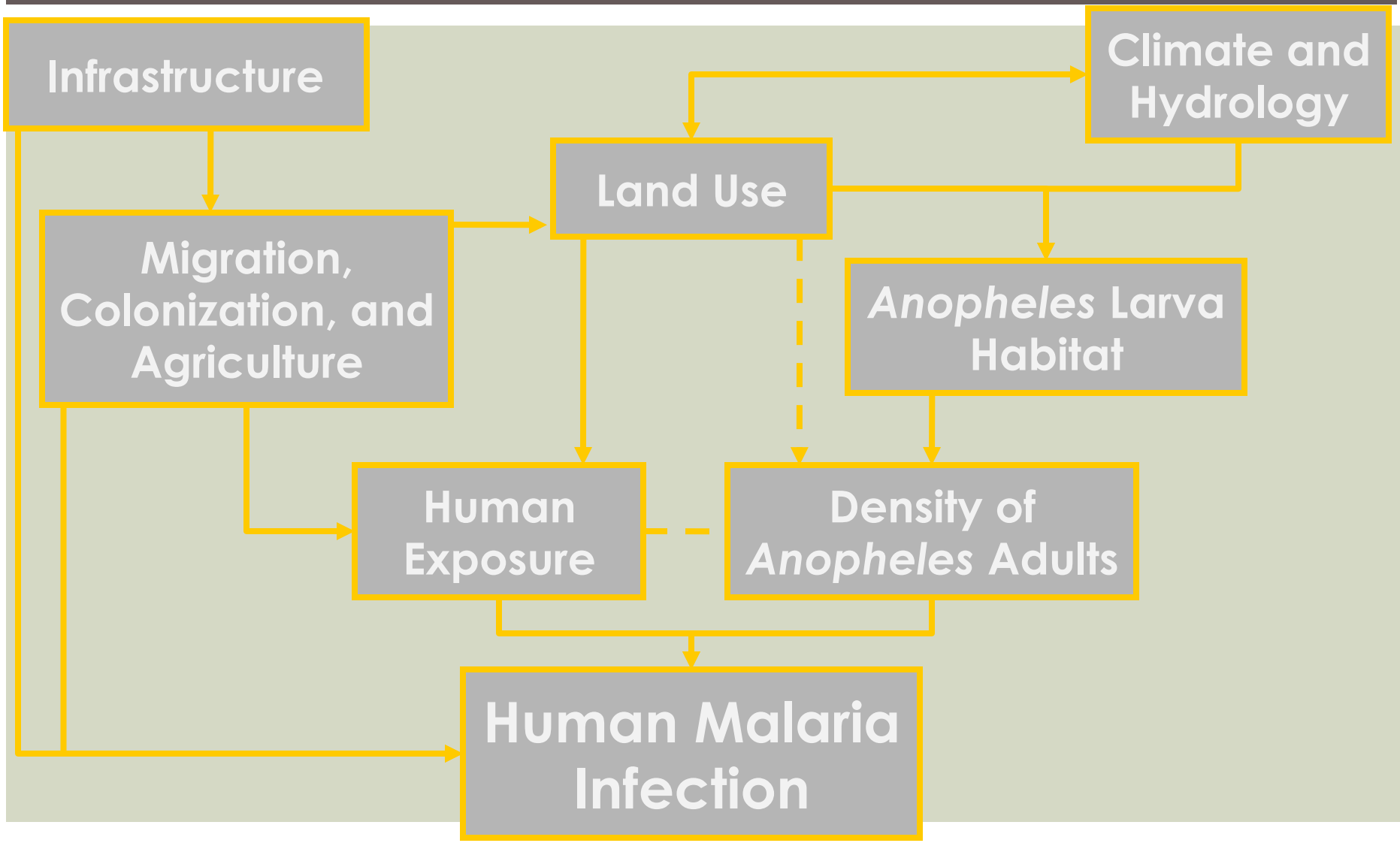
MALARIA ON THE AMAZON FRONTIER



MALARIA ON THE AMAZON FRONTIER



MALARIA ON THE AMAZON FRONTIER

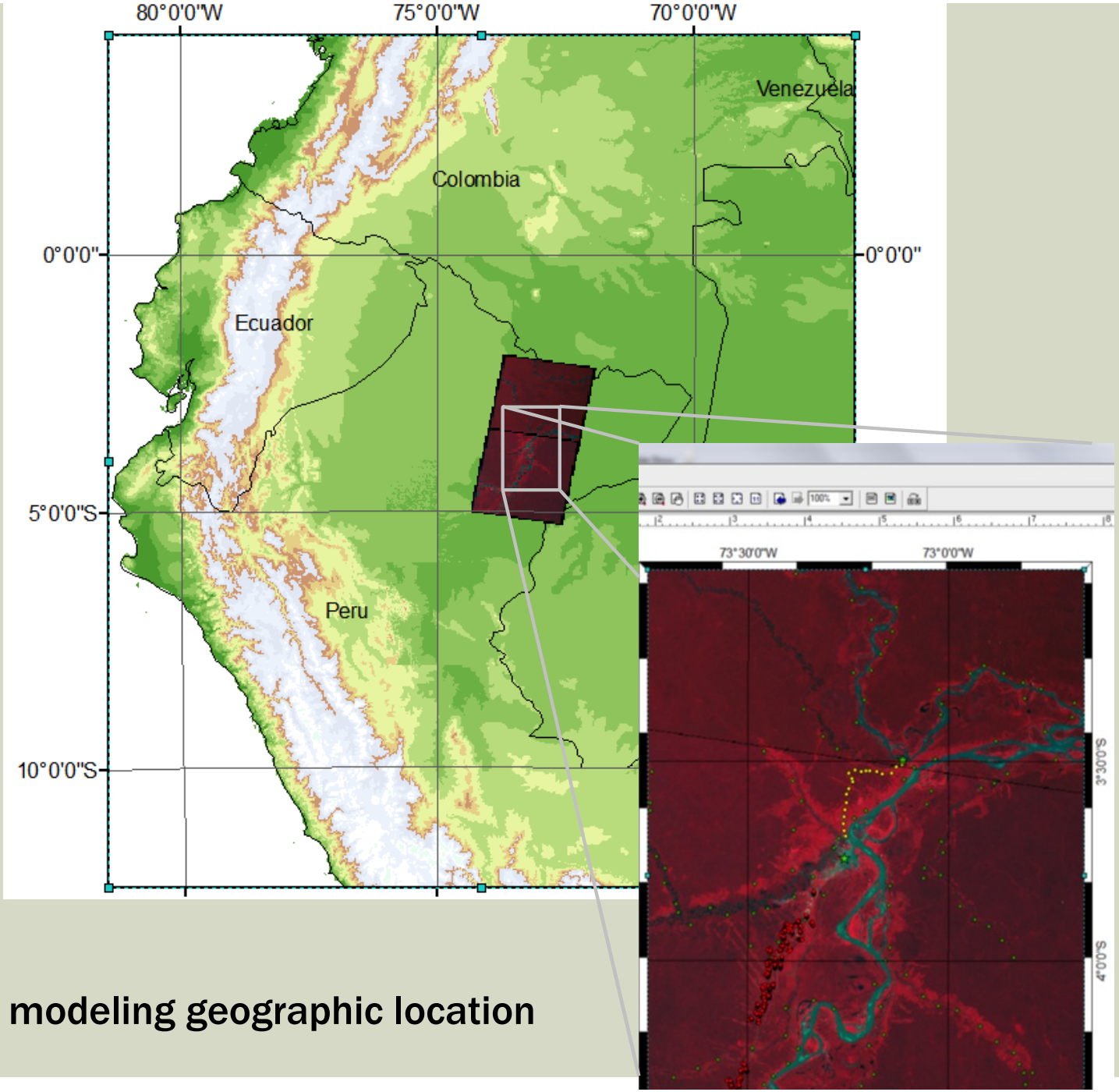


APPROACH

- Spatio-temporal Ecological *Anopheles* model
  - Input 1: Satellite-based land cover maps
  - Input 2: Meteorological data
  - Input 3: Land Data Assimilation System
- Human Activities and Settlements Map
  - Input 1: Satellite and *in situ* mapping
  - Input 2: Census and Economic data
- Eco-epidemiological Malaria Transmission Model
  - Application: Risk monitoring and prediction

STATE OF ANALYSIS

- Land Surface Model simulations show strong potential to inform predictions of *Anopheles* distribution.
- The relationship between land cover and mosquito distribution is robust and species-specific, and it appears to be strongest at 3-8km radius of influence.
- Climate variability appears to affect total mosquito abundance, while land cover influences the relative density of vector species. Infection rates now being introduced to the model.
- Individual and population scale malaria risk modeling: LDAS / climate variables currently being integrated with epidemiologic surveillance data.

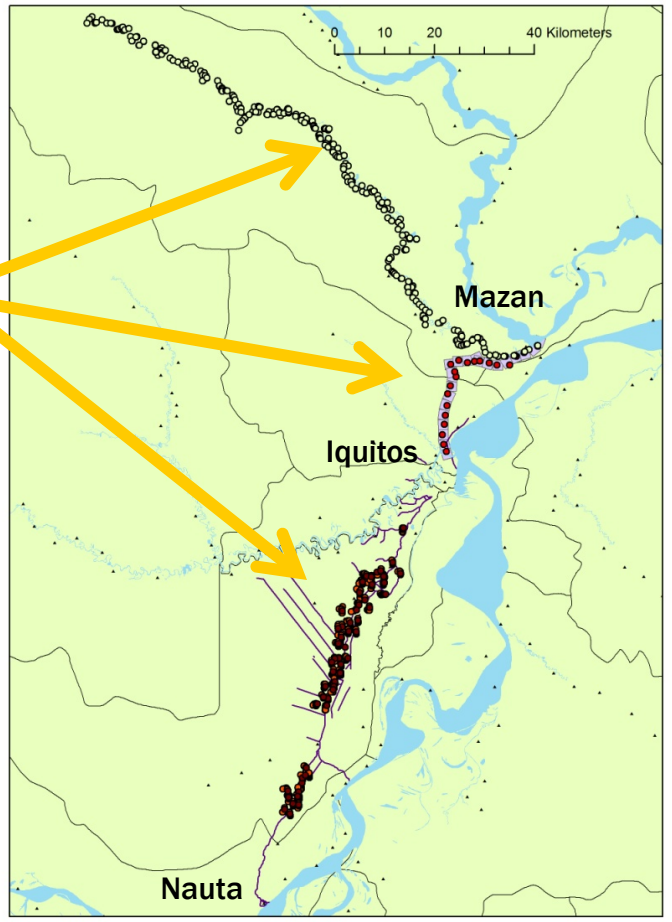


Ecological modeling geographic location

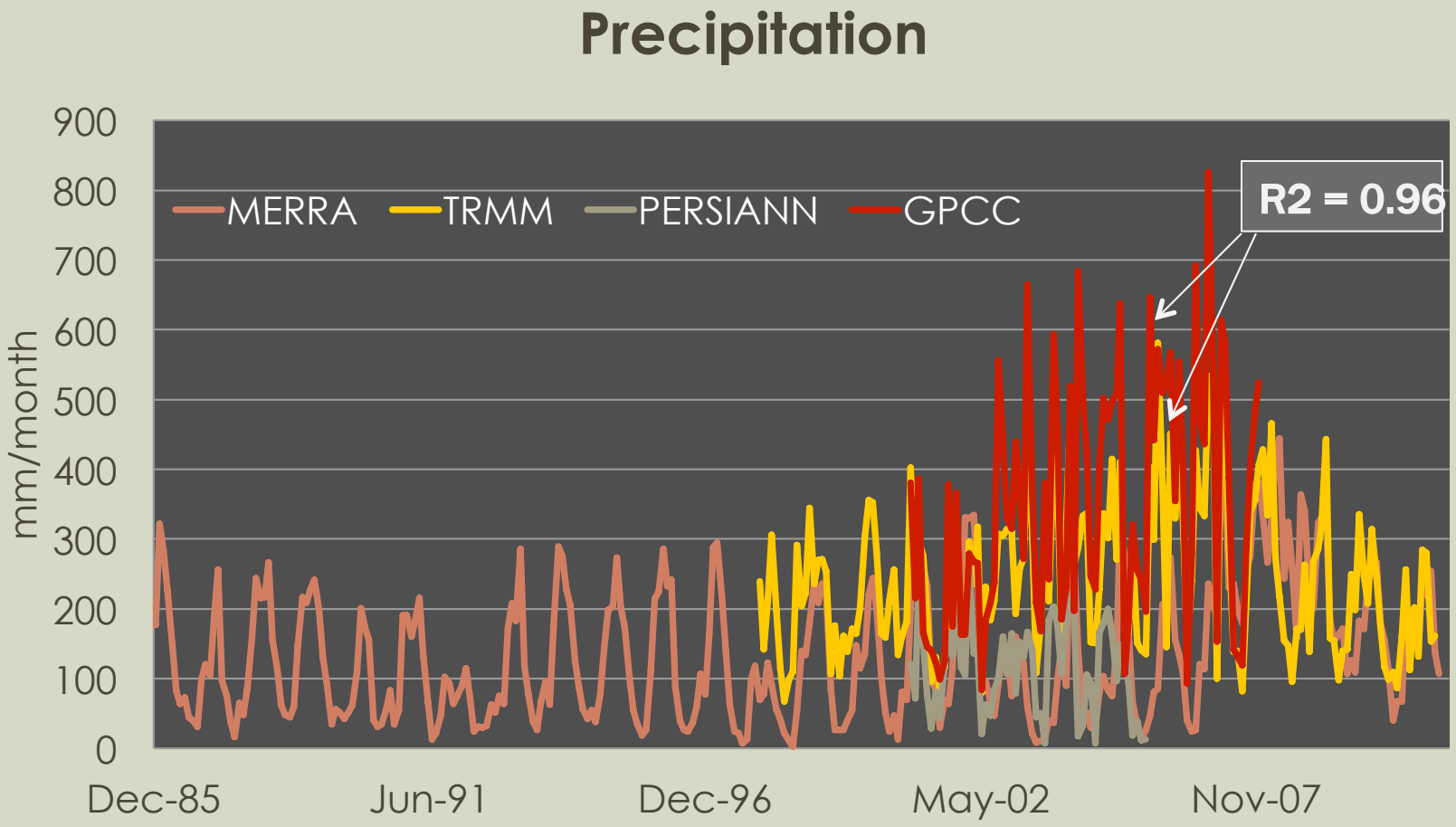
ANOPHELES COLLECTIONS

Mosquito Collection

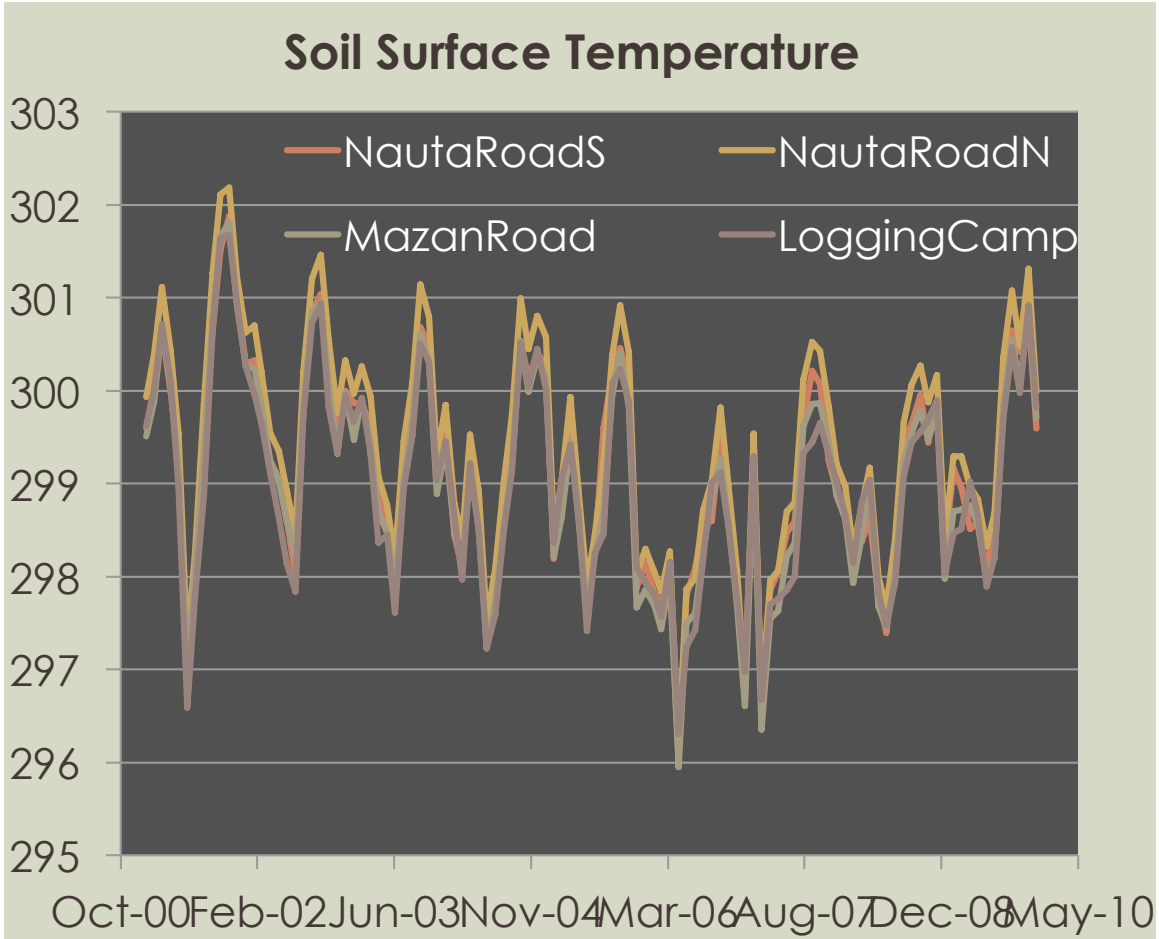
- Iquitos-Nauta road: 1999-2001
- Iquitos-Mazan road: 2007-2011
- Additional survey of logging camps

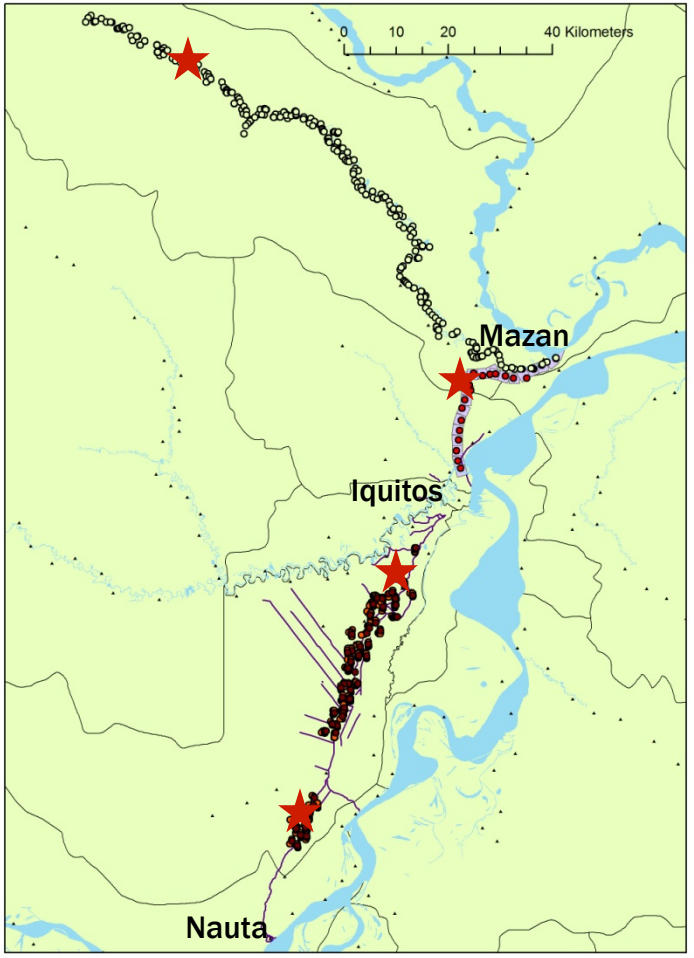


METEOROLOGICAL DATA

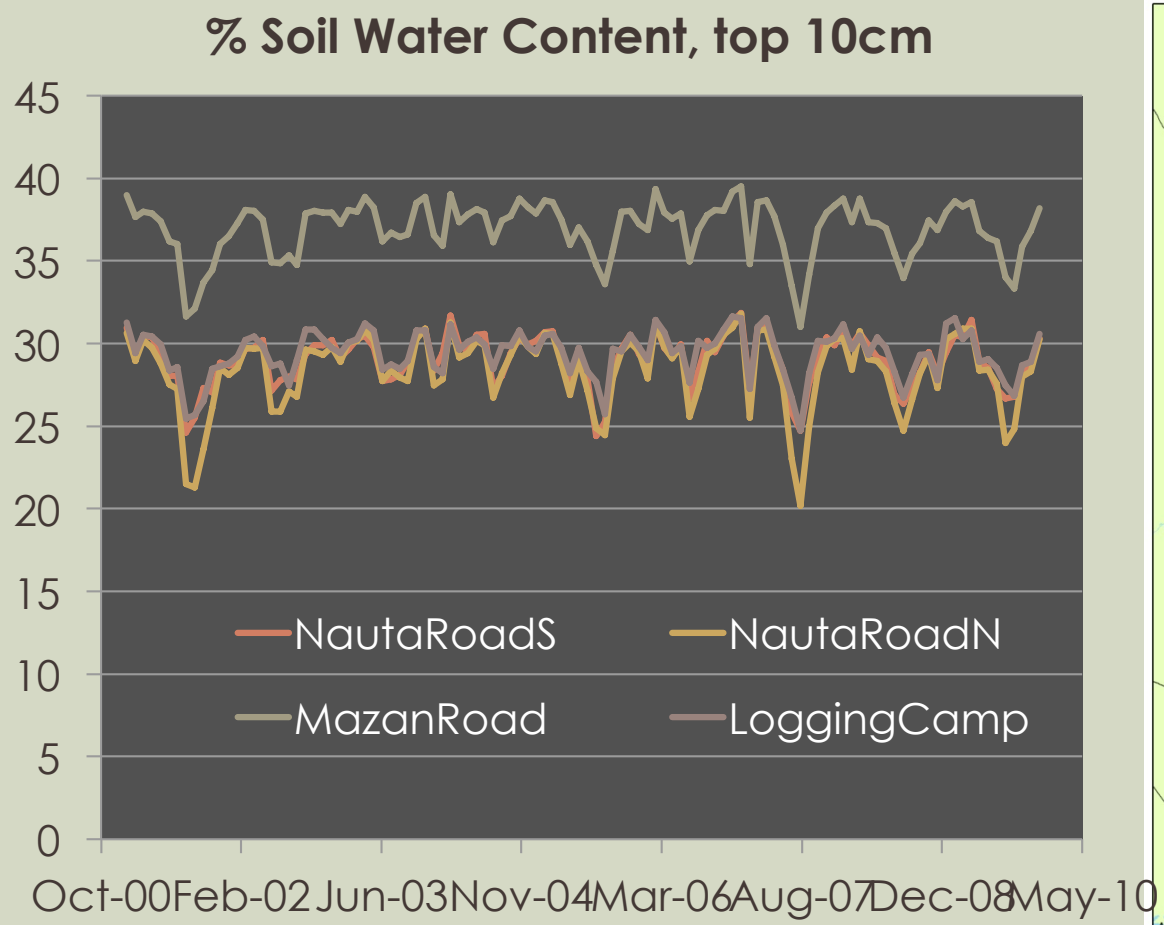


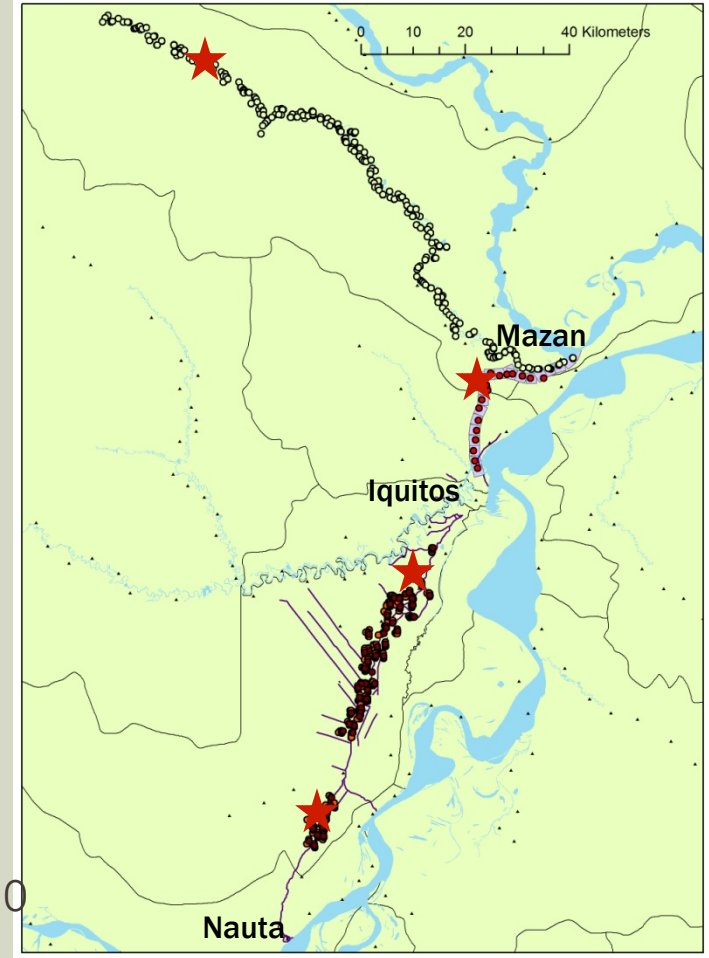
LAND DATA ASSIMILATION SYSTEM





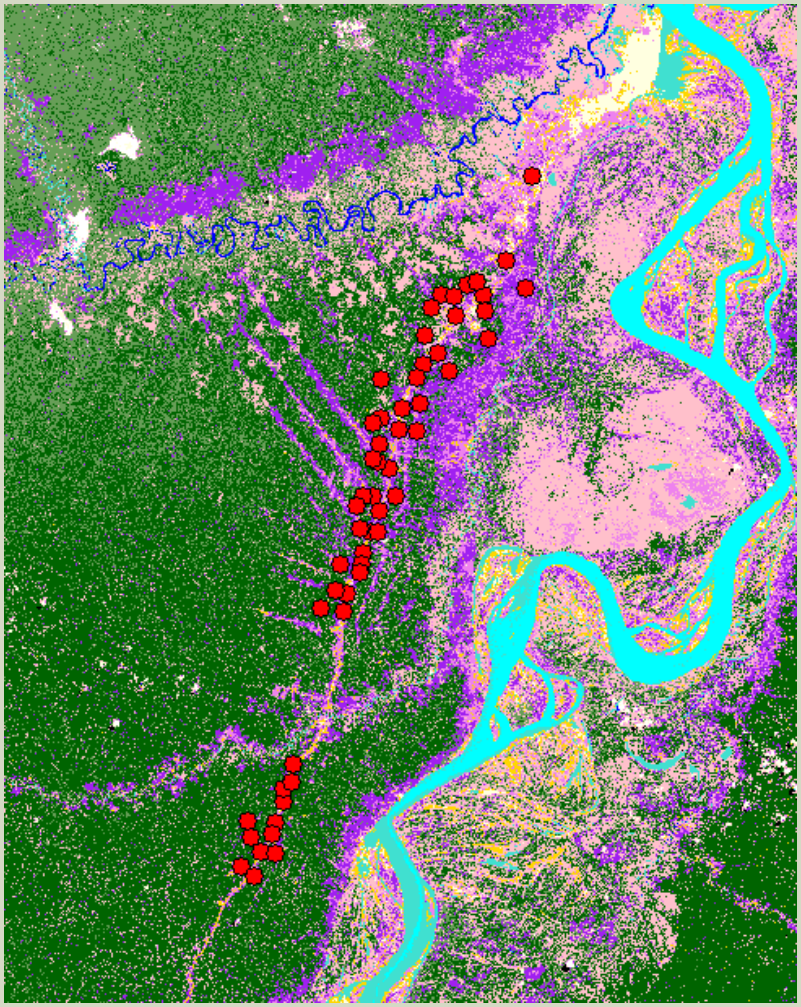
LAND DATA ASSIMILATION SYSTEM



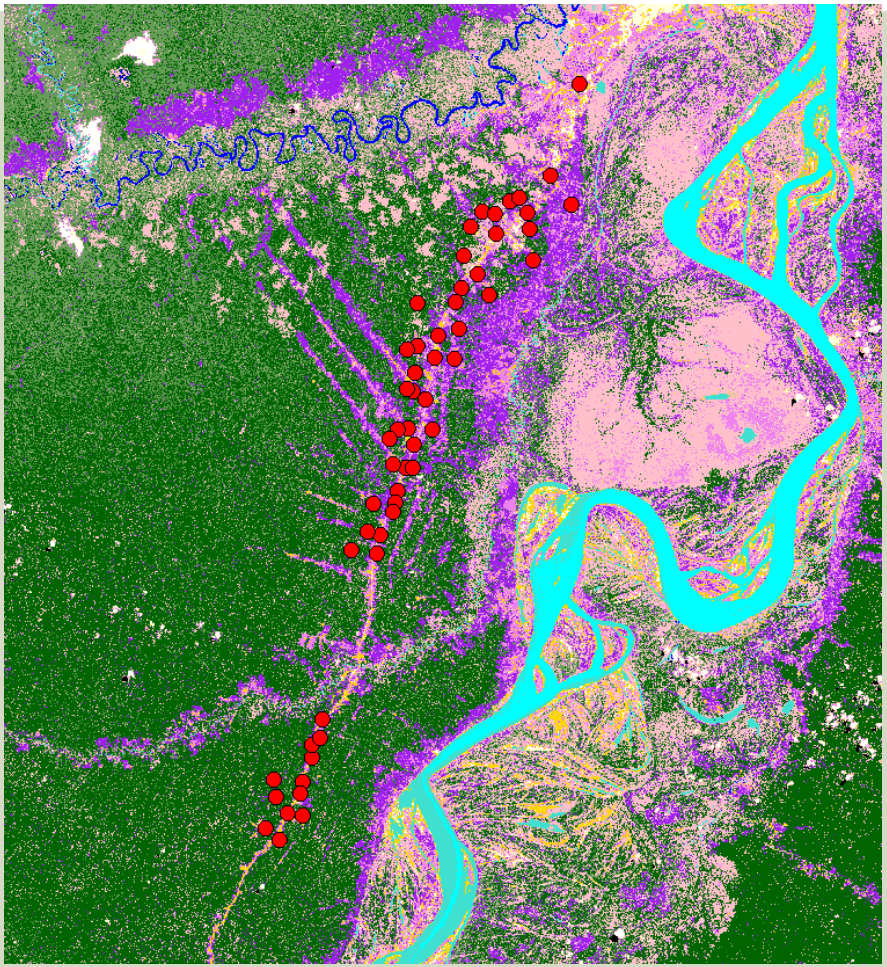


LAND COVER CHANGE

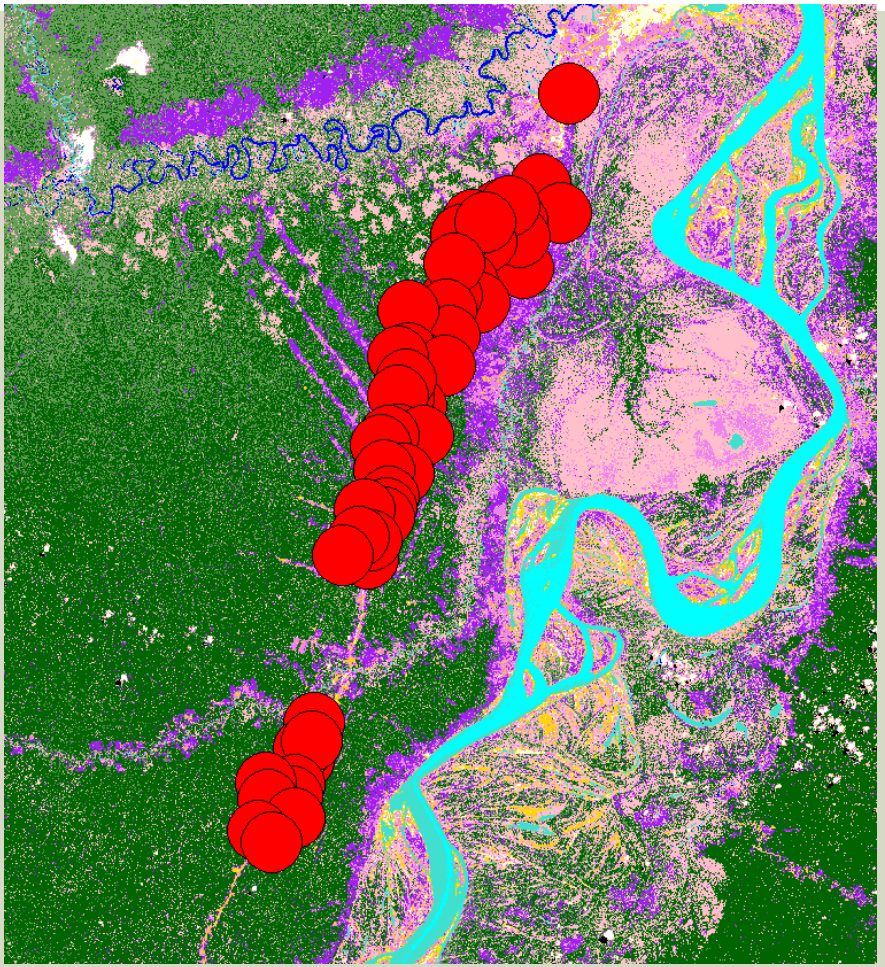
- **Deforestation & Infrastructure Expansion**
  - Oil Exploration
  - Highway construction
  - Urban growth
- 12 class supervised classification on Landsat
- Nauta-Iquitos road in 2001 and Iquitos-Mazan road in 2009
- Deforestation/reforestation was quantified through comparisons with earlier images



SPATIALLY EXPLICIT *ANOPHELES* MODEL

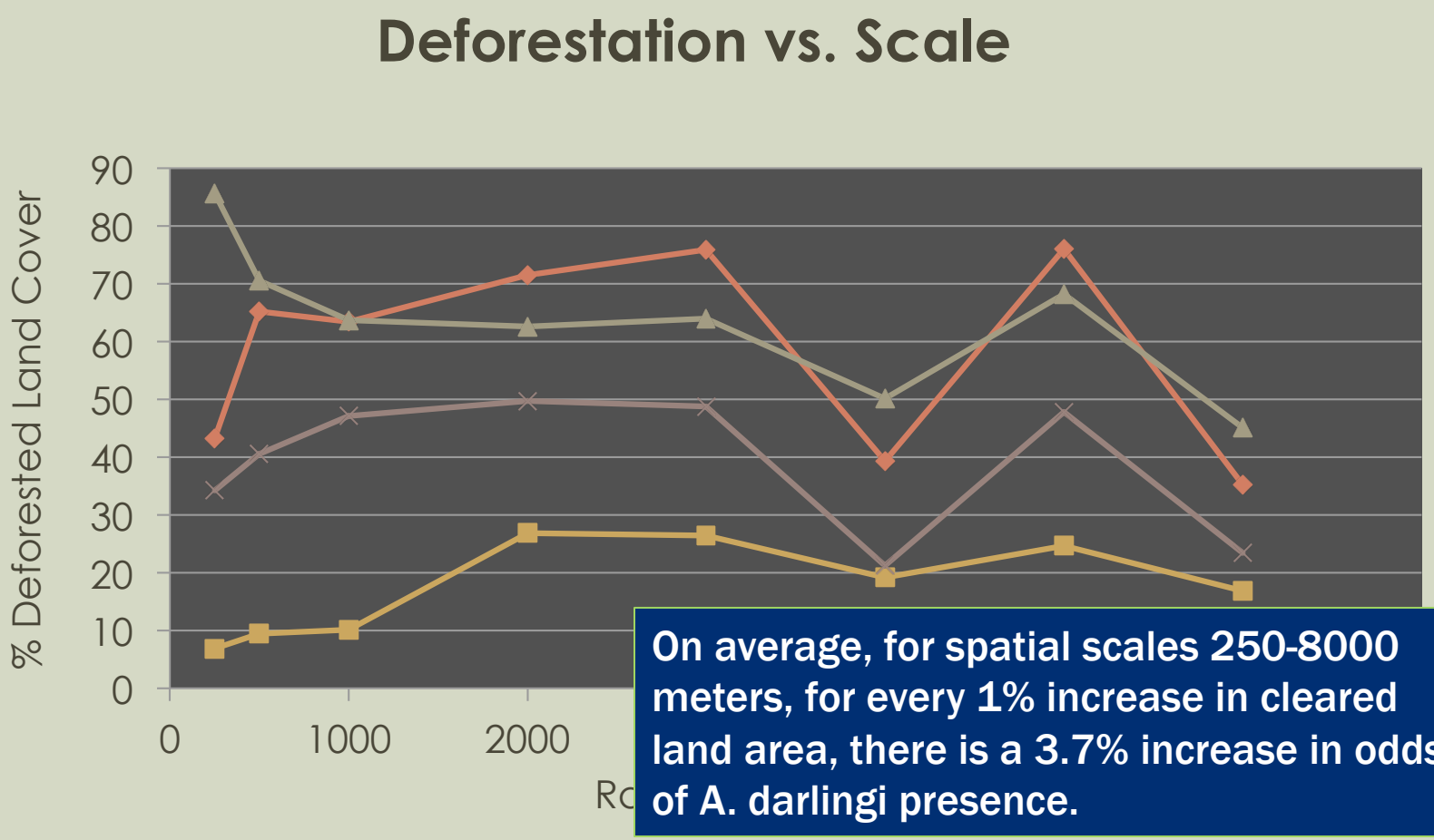


250 m radius



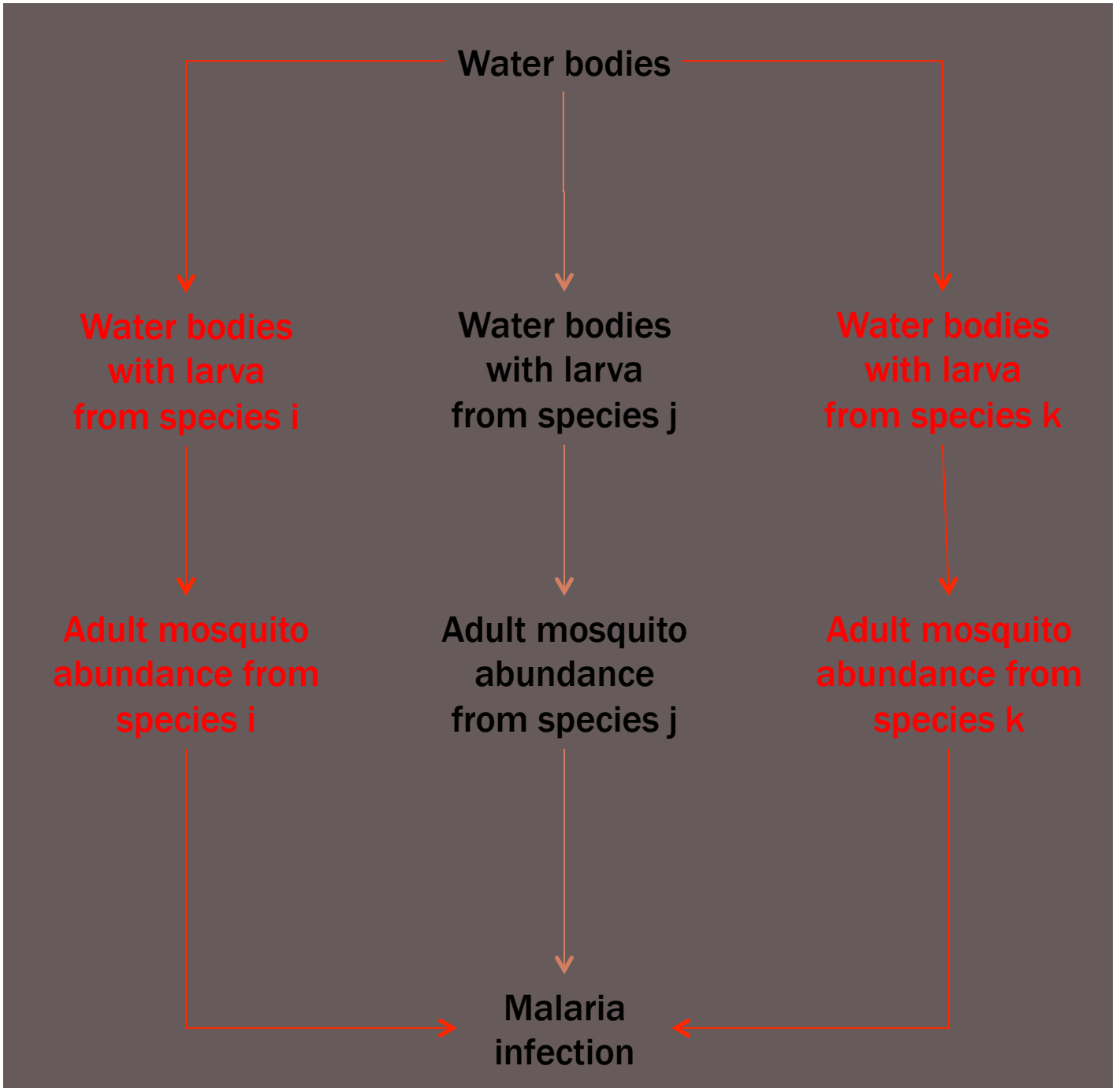
1000 m radius

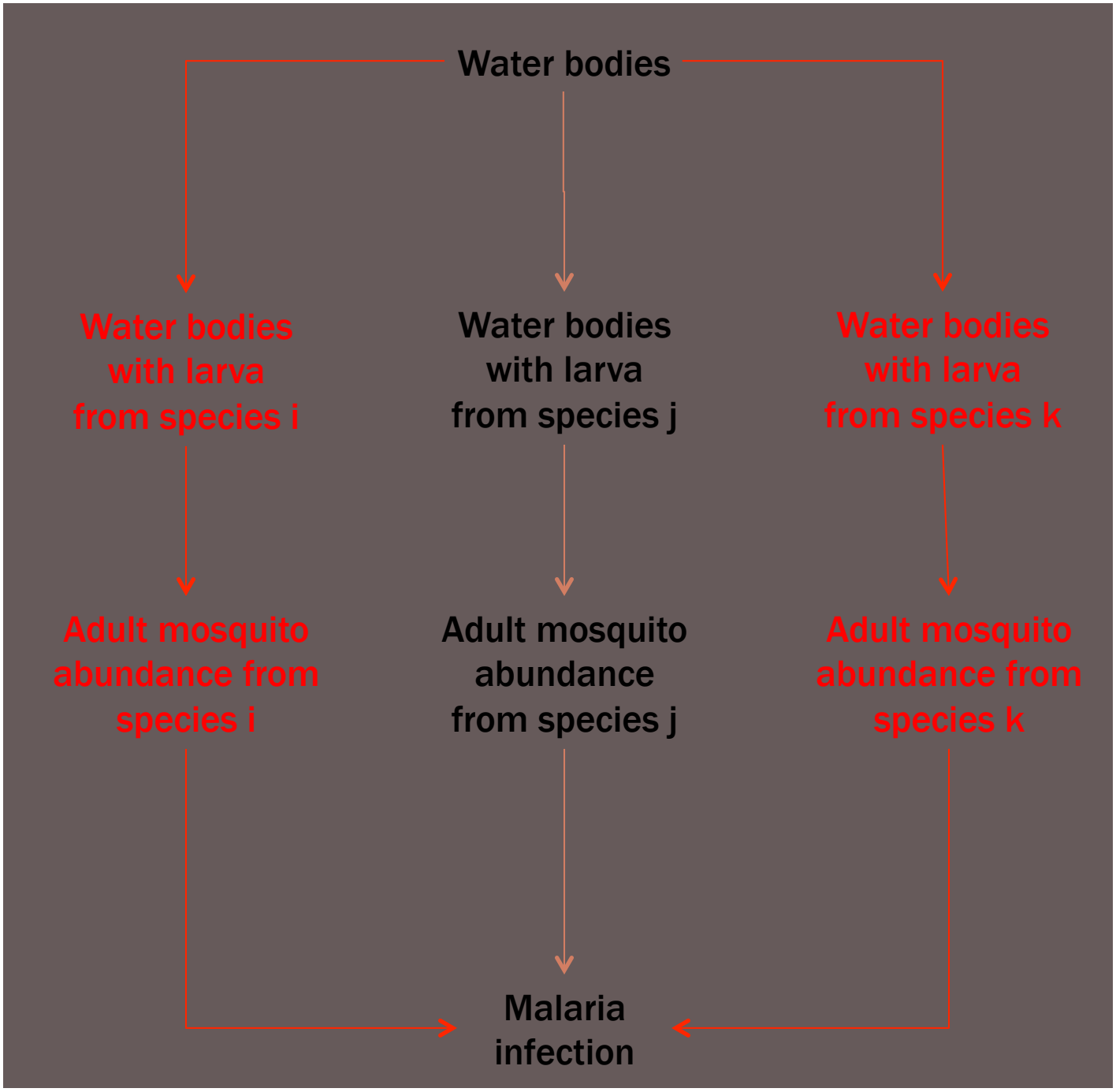
SPATIALLY EXPLICIT *ANOPHELES* MODEL



On average, for spatial scales 250-8000 meters, for every 1% increase in cleared land area, there is a 3.7% increase in odds of A. darlingi presence.

Water bodies
Water bodies with larva
Adult mosquito abundance
Malaria infection


Water bodies
Water bodies with larva from species i
Water bodies with larva from species j
Water bodies with larva from species k
Adult mosquito abundance from species i
Adult mosquito abundance from species j
Adult mosquito abundance from species k
Malaria infection

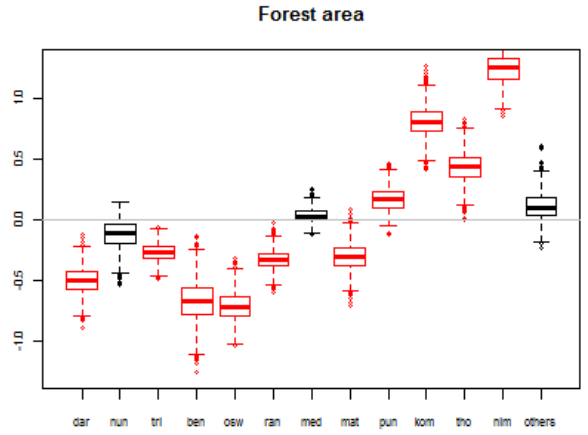


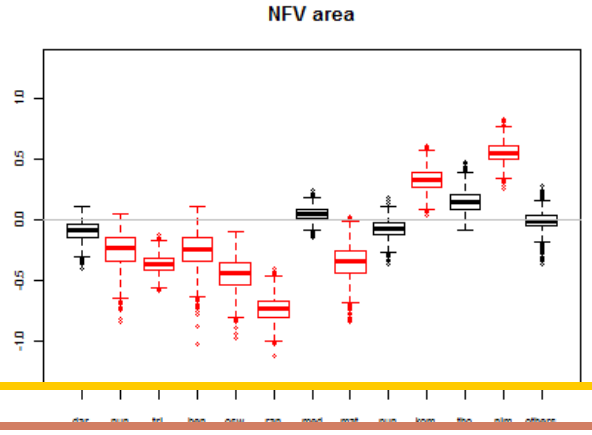
Model 1: water bodies

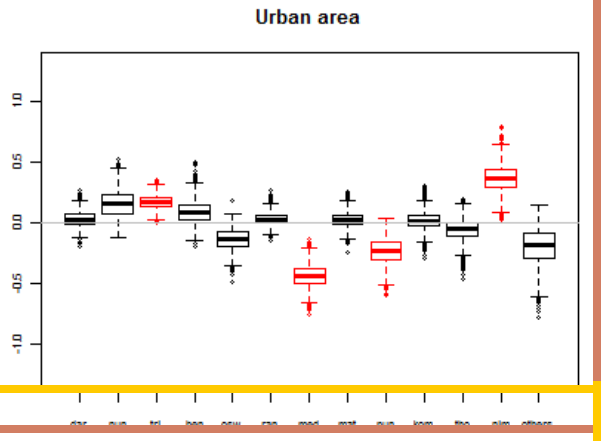
Model 2: larva

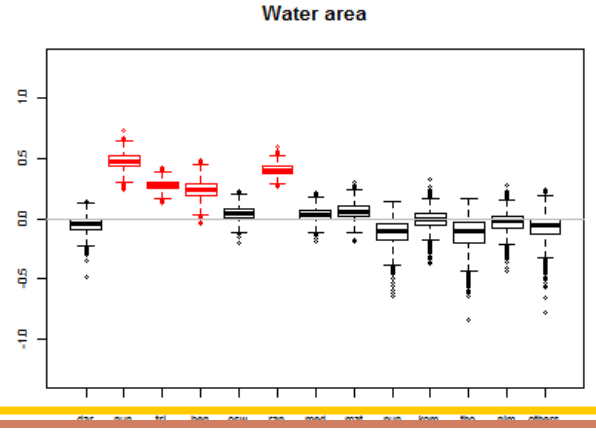
Model 3: adult mosq.

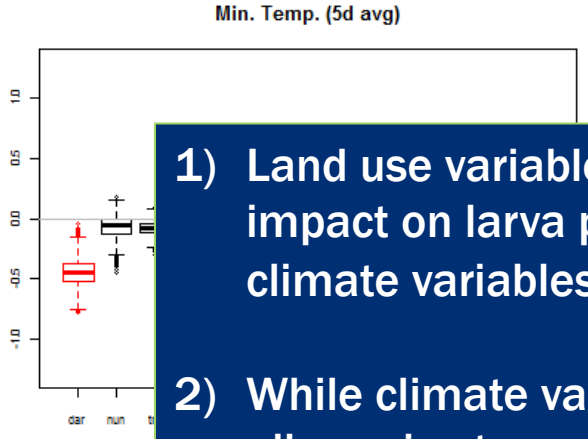
Model 4: infection

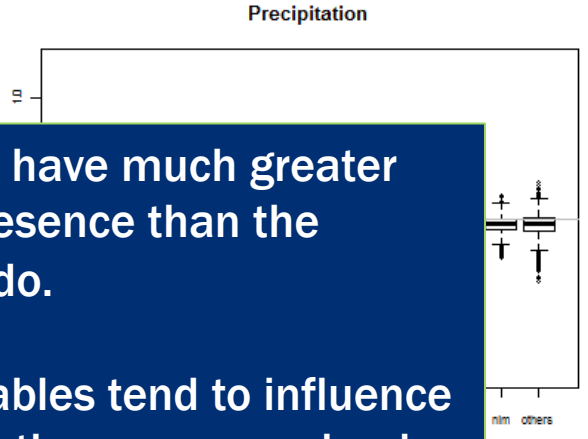


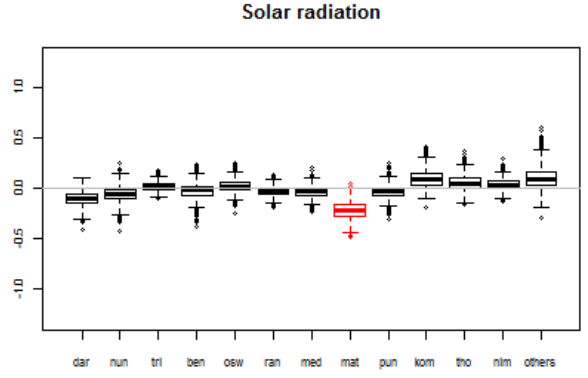


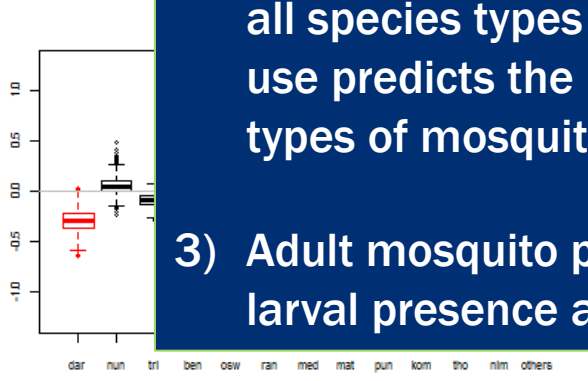


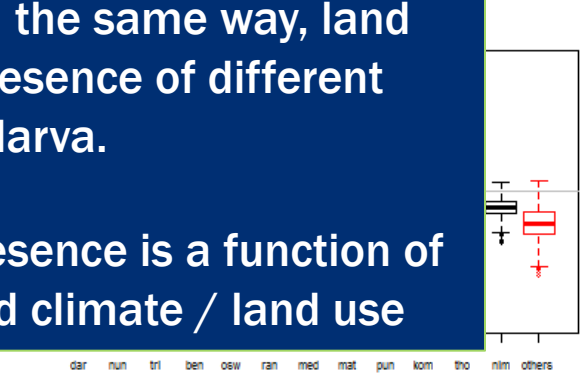












1) Land use variables have much greater impact on larva presence than the climate variables do.

2) While climate variables tend to influence all species types in the same way, land use predicts the presence of different types of mosquito larva.

3) Adult mosquito presence is a function of larval presence and climate / land use

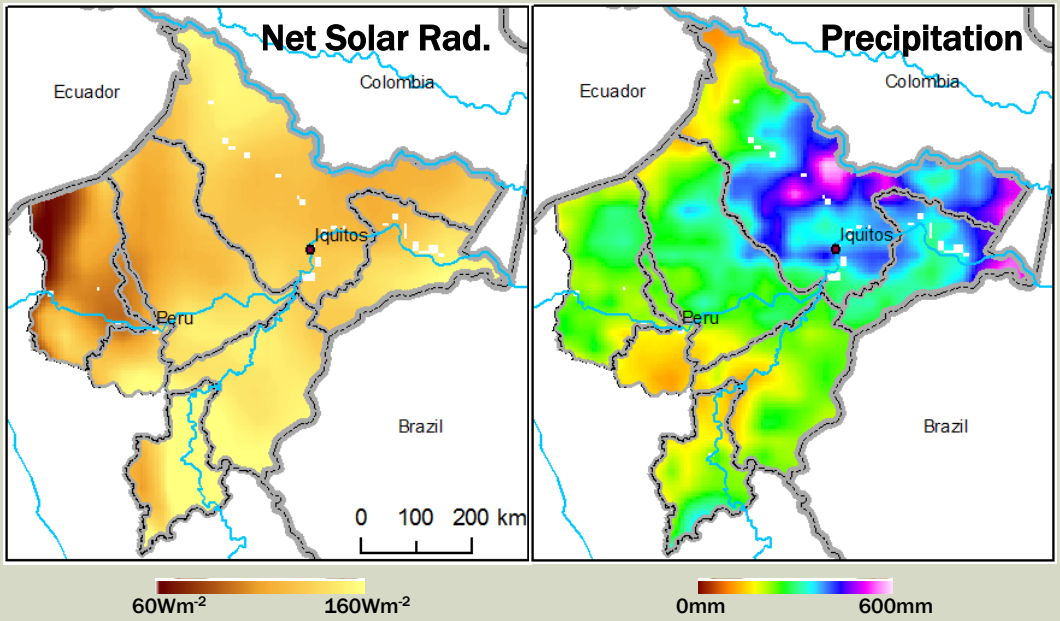
POPULATION LEVEL MODELING

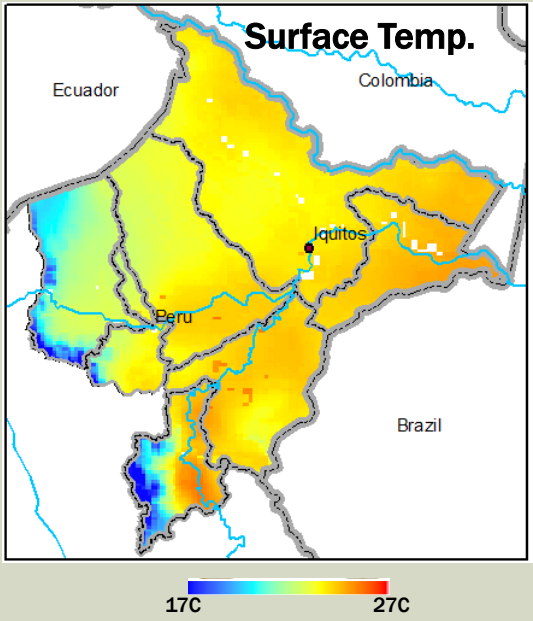
- We are coupling the individual analysis with complementary population level analysis.

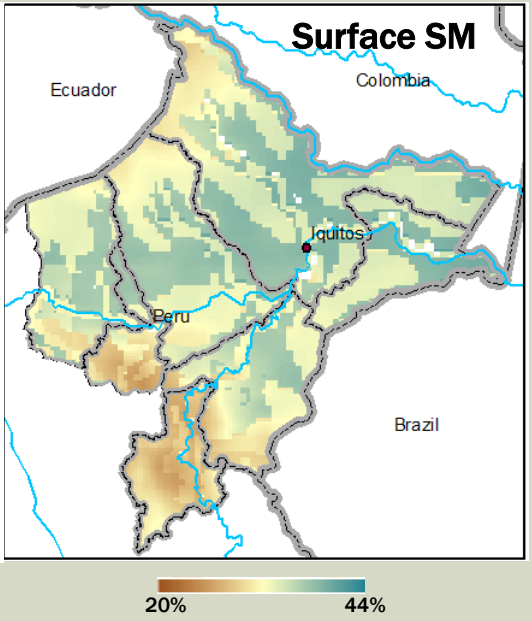
- Inputs:
  - Epidemiologic surveillance data for 2000-2012 from the Regional Health Directorate.
  - LDAS/climate variables for each malaria case
  - MODIS land cover products

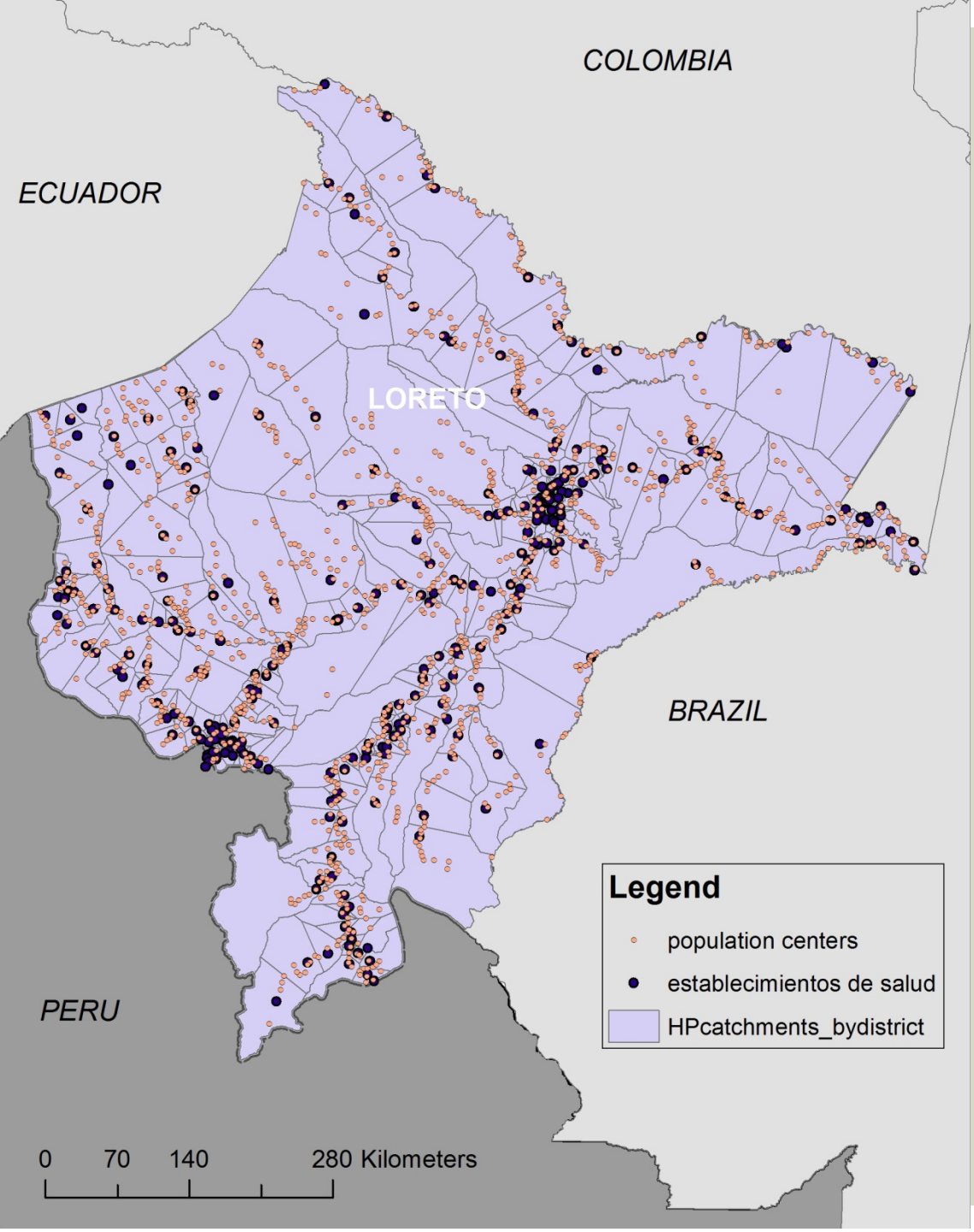
- Model:
  - Expected number of cases per health post per week is dependent upon local temperature, precipitation, soil moisture, season, population density and human migration.

Extended LDAS Simulations



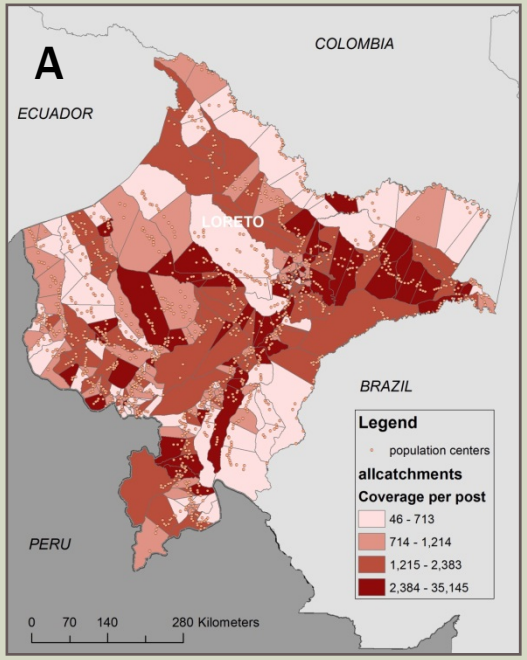


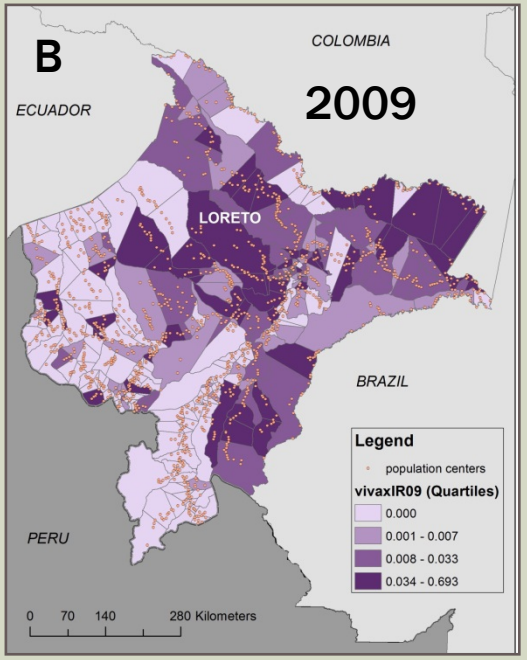


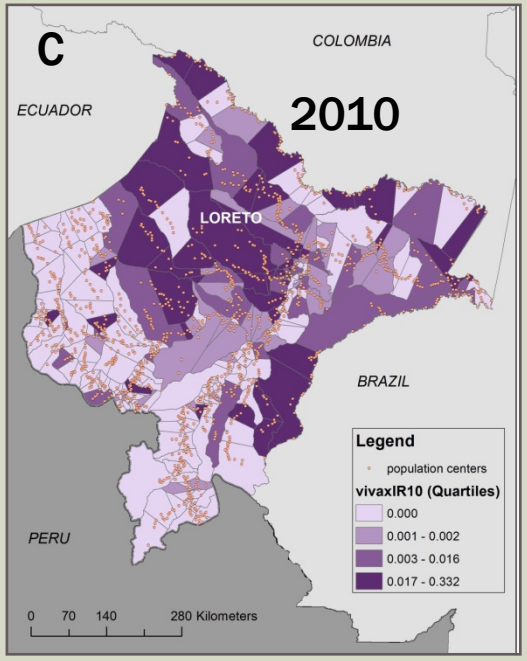


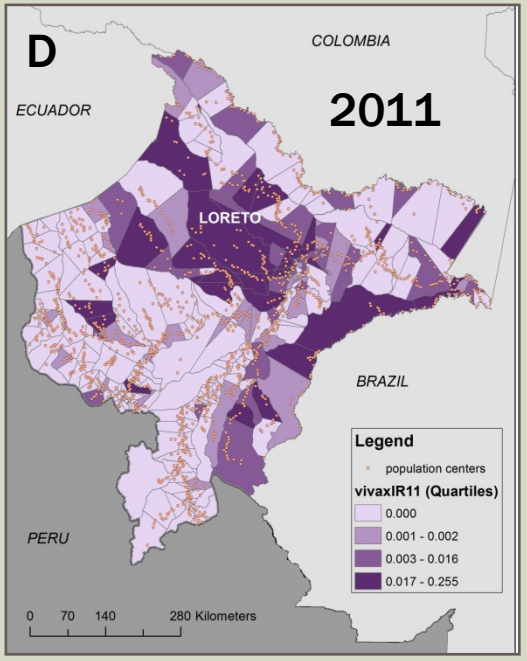
Catchment areas for all Loreto health posts (establacimientos, n=308) by district

*draft map – do not reproduce





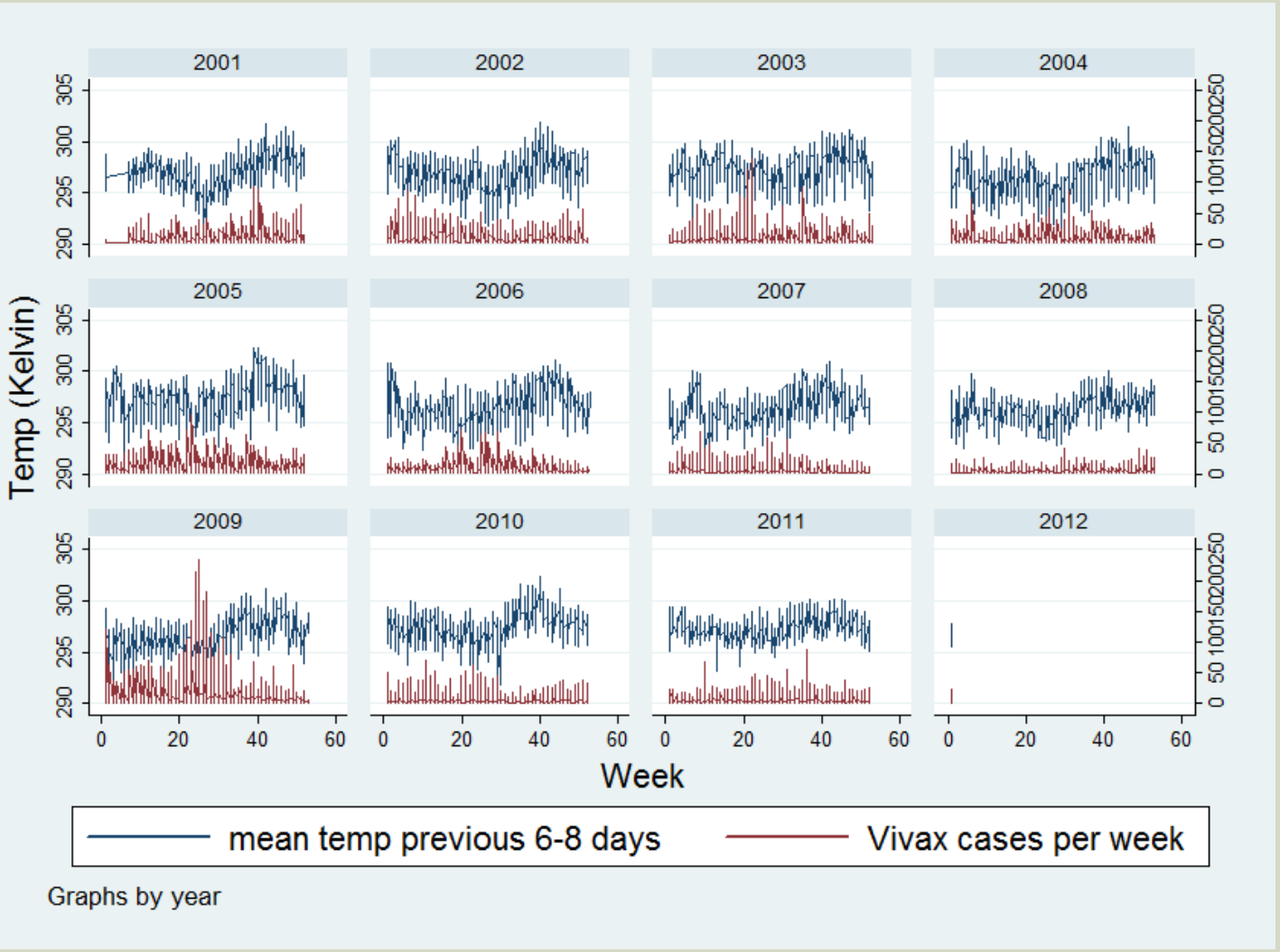




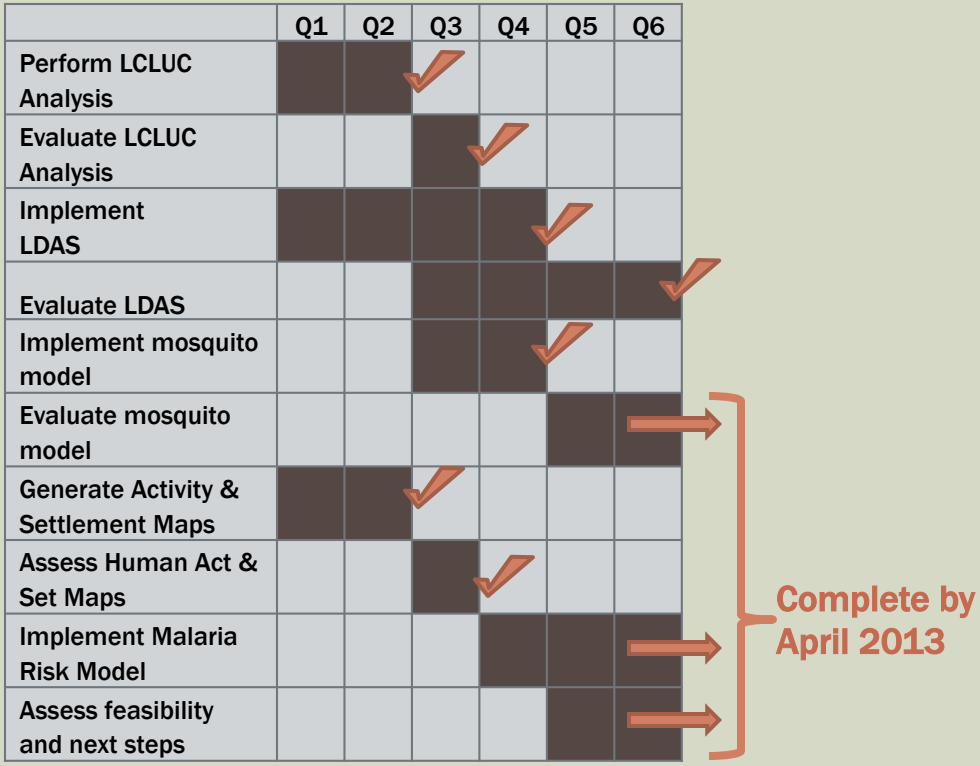
A. Population coverage by health post
B. Vivax malaria rate 2009
C. Vivax malaria rate 2010
D. Vivax malaria rate 2011

*draft maps – do not reproduce

INTEGRATING CLIMATE AND SURVEILLANCE DATA



TIMELINE AND BUDGET



- Total budget: $136K
- Budget Received: $61K*
- Spent: $62K*
- Spent + Committed: $83K*
- A no-cost extension has been approved

* August 2012 figures

NEXT STEPS

- Complete evaluation and refinement of species-specific mosquito model
- Finalize population level malaria risk model
- Work with end-user partners to ensure that the products are taking on a useful form
- Ensure further development of the feasibility study (W. Pan NIH R01 proposal submitted July 2012)

THANK YOU